KING COUNTY CONVEYANCE SYSTEM IMPROVEMENT PROJECT

CONVEYANCE SYSTEM COST ESTIMATES

TASK 250 REPORT

SEPTEMBER 2001

HDR

in association with

Brown and Caldwell

and

Herrara Environmental

TABLE OF CONTENTS

Introduction 1
Background 1
Types of Cost Estimates 2
Preliminary/Order of Magnitude Estimates 2
Budget Estimates 3
Final/Definitive Estimates 3
Refining Planning Level Estimates 3
Cost Indexes 3
Pipes – Gravity Sewers and Force Mains 4
Pipeline Cost Variability 4
Pipeline Cost Model 5
Pipes - Microtunneling 7
Pipes - Conventional Tunneling 8
Pump Stations 9
Off-line Storage Facilities 11
Total Project Costs 12

LIST OF FIGURES

Figure 1. Cost Development Relationships 2
Figure 2. Pump Station Construction Cost Curves 10
Figure 3. CSO/SSO Off-line Storage Facilities 11

LIST OF TABLES

Table 1. Pipeline Costs 6
Table 2. Modeled Gravity Sewer Construction Costs 7
Table 3. Open–Cut Base Construction Unit Costs 7
Table 4. Microtunneling Unit Costs 8
Table 5. Tunneling Unit Costs 9
Table 6. Pump Station Unit Costs 9
Table 7. Task Costs as Percent of the Total Project Cost 12

INTRODUCTION

This memo (originally written in October 1999) presents the basis for estimating planning level costs for conveyance improvements. The parameters presented herein should only be used at the planning level when precise information beyond the size of the conveyance facilities is difficult to obtain. The objective of this memo is to develop simple cost estimating tools, e.g., cost curves, models, and tables for planning level cost estimates for the following King County Wastewater Treatment Division (KCWTD) improvements:

- Gravity sewers,
- Force mains,
- Pump stations,
- Tunnels, and
- Storage.

BACKGROUND

Accurate cost estimates are essential to permit budgetary planning for capital improvements and properly develop sewer rates. For gravity sewers, construction costs can vary with depth, surface restoration requirements, construction methods, and several other factors. A basis for conveyance system cost estimates was developed for the Wastewater 2020 project and related Regional Wastewater Services Plan (RWSP). This current effort is intended to provide refined construction cost estimates by accounting for various site-specific conditions and construction methods that affect the project costs. Only conveyance system construction costs are addressed at this time. The relationship between the construction costs and other costs associated with a capital improvement project are depicted in Figure 1.

Changes in the construction method and scope of the project can lead to significant changes in cost from the initial conceptualization of the project thorough construction. As the project evolves, differences between the baseline budget and the current budget will accumulate. These differences (Trends) will reflect the gradual change from the criteria representing the concept project to the criteria representing the actual project. As a part of this review, the KCWTD CSI team will develop a Trend Reporting System (TRS).

The TRS is designed to track and control project scopes, cost and schedule. It identifies changes in the project scope, scope of services for engineering, procurement and construction of the project; and allows the project team to examine and take corrective actions before the completion of the design. The objective of this system is to document cost and schedule impacts affecting the design and construction of a project during the planning stage.

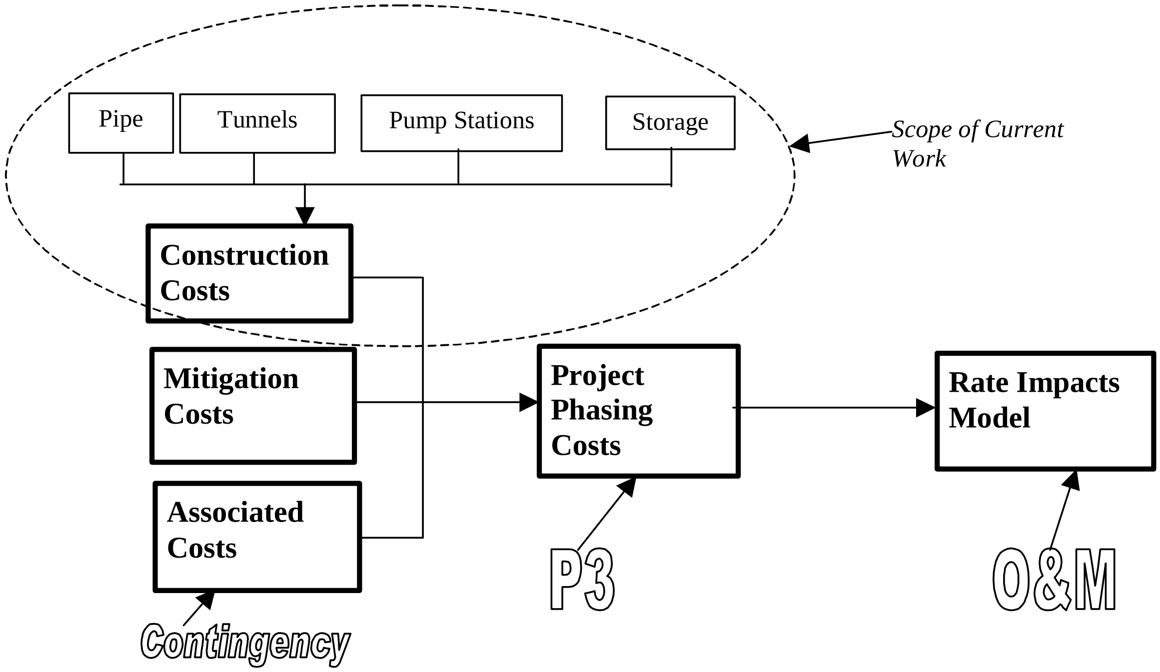

Figure 1. Cost Development Relationships

TYPES OF COST ESTIMATES

There are at least three broad categories of cost estimates based upon the degree of definition of the project as outlined in *Successful Estimating Methods: From Concept to Bid* by RS Means and the *Association for the Advancement of Cost Engineering (AACE) Standard No. 10S-90 – Standard Cost Engineering Terminology*. The typical levels of cost estimates are as follows:

- Preliminary/Order of Magnitude
- Budget
- Final/Definitive

In general, the greater the definition and level of detail available about a project, the more accurate the cost estimate can be expected to be.

Preliminary/Order of Magnitude Estimates

Order of magnitude estimates are often used in planning level reports to provide a bracketed range of costs of a conceptually defined project. They are used to make large scale planning decisions and reduce the number of alternatives that may be considered in more detail.
The tools used to achieve these estimates include cost curves, scale-up or scale-down factors, and approximate ratio estimates. The expected accuracy is no better than within plus 50 percent to minus 30 percent.

Budget Estimates

Project budget estimates are prepared with the use of layouts, specific quantities and equipment details. It is normally expected that an estimate of this type would be accurate within plus 30 percent to minus 15 percent.

Final/Definitive Estimates

Final definitive (detailed) estimates can be prepared when the design and contract documents have been completed, or are essentially complete. For King County projects, these final estimates are typically referred to as Engineer's Estimates and are used to estimate the final anticipated competitive bid price of a project. It is normally expected that an estimate of this type would be accurate within plus 15 percent and minus 5 percent.

Refining Planning Level Estimates

The purpose of this memorandum is as follows:

1. Provide one easily referenced source of information to help the project team determine budgetary costs of projects evaluated in the King County Conveyance System Improvements (CSI) Project.

2. Bridge the gap between Preliminary/Order of Magnitude cost estimates typically used in planning level reports and more refined Budget level estimates that may be prepared in planning level estimates if more information is available.

The goal is to provide CSI estimates that are both comparable with one another and are more accurate in predicting the ultimate capital cost of planning projects. It is hoped that if adequate information is available, the resulting planning level estimates can be typically within the Budget cost estimate accuracy of plus 30 percent to minus 15 percent.

COST INDEXES

Historical construction costs, cost estimating guides and other sources of information were used to develop parameters that could be used to create refined planning level estimates for KCWTD capital improvement projects. Historical costs were adjusted for inflation by using a construction cost index. Several construction cost indexes are available including the Engineering News Record Construction Cost Index (ENR CCI) for Seattle, the Handy Whitman Index, several EPA cost indexes, and the US Bureau of Reclamation Construction Cost Trends. The ENR Seattle CCI was selected to update local historical costs because it is specific to the Seattle metropolitan area, updated on a regular basis, and is in common use. The mid-year 1995 ENR Seattle CCI that would apply to the Wastewater 2020 Plus budgetary estimates was 5,870. The late 1999, early 2000 ENR Seattle CCI is approximately 7,000, which represents an annual cost escalation of approximately 3.6 percent or a total of 19 percent over the five year period.

PIPES – GRAVITY SEWERS AND FORCE MAINS

The KCWTD system contains over 260 miles of pipelines. Most sections of gravity sewer can be installed utilizing open-cut trench construction. Standard gravity sewers comprise approximately two-thirds of the total length of pipelines owned by the County. Costs for open-cut gravity sewer and force main construction were compiled from previous Metro/KCWTD projects. These costs for previous projects are included in Appendix A.

Pipeline Cost Variability

Pipeline costs are functions of several site-specific factors such as type of construction, right-of-way, depth, number of conflicting utilities, subsurface conditions, and amount of restoration. These site-specific factors typically have a higher percentage of cost impact on smaller diameter pipelines than larger diameter pipelines, since the cost of the pipe and installation is relatively small in comparison to these site-specific factors.

Site-specific factors that affect pipeline construction cost include the following:

- **Right-of-Way Acquisition –** Acquisition of new right-of-way can add to the cost of pipeline construction over the cost of new pipes within existing right-of-way. For Wastewater 2020 Plus, a right-of-way land costs varied from $6.90 per square foot for rural areas to $18.00 per square foot for urbanized areas plus a contingency of 45 percent.
- **Construction Method –** Specialized construction techniques, such as microtunneling, directional drilling, and pier supports can significantly increase the cost of pipeline construction. Specialized construction is often required to traverse arterial roadways, railroads, and topographical barriers such as hills, waterways, and wetlands.
- **Excavation Depth –** Increasing the trench depth from minimum cover to a greater depth to maintain adequate slope or avoid other utilities significantly impacts the cost of excavation and backfill for open-cut trench projects. The effect of greater depth will be determined based upon excavation and backfill quantities and unit prices.
- **Dewatering –** In most cases trench sumps are used to remove small volumes of seepage into the trench during construction. If the ground water elevation is within a foot of or above the bottom of the trench, dewatering wells or well points may be required to draw down the ground water in the vicinity of the trench so that the pipe can be installed and the backfill compacted. The costs for dewatering can vary significantly depending upon geotechnical conditions and water volumes. Costs for dewatering are $5 for trench sumps and pumping to more than $200 per lineal foot for dewatering wells for larger diameter pipe. Unit multipliers are based upon the diameter of the pipe with costs varying between $5 and $120 per foot.
- **Subsurface Conditions –** When native soils are unsuitable for trench backfill, imported backfill or controlled density fill may be required, especially in the pipe zone. In peat or other poor foundation soils, pile supported pipelines may be required. The cost for imported backfill is typically $25-$30 per ton and there are approximately 1.85 tons of fill per cubic yard. Imported backfill will add roughly 30 percent to the cost of open-cut excavation.

- **Existing Utilities –** Avoiding and/or relocating existing utilities may be required in more highly developed urbanized areas. The "base" project estimate assumes that there will be a limited number of existing utilities to relocate and/or connect.
- **Concurrent Parallel Pipe Construction –** This type of construction may be used for new force mains. If the parallel force mains share a common trench, the installed unit costs of the second pipe may be reduced by as much as 50 percent below the typical unit costs for a single pipe.
- **Pipe Materials –** Gravity sewers are typically composed of concrete. However, force mains are generally cement mortar lined ductile iron. Pipe materials such as PVC, HDPE, or fiberglass may be used in corrosive conditions. While force mains may be constructed of more expensive pipe materials, manholes are not required as they are for gravity sewers.
- **Traffic Control –** Construction in and adjacent to busy arterials can add significantly to the construction cost over those pipelines that may be built in more open or less traveled right-of-way.
- **Surface Restoration –** Surface restoration of roadways and adjacent areas can substantially increase the cost of open trench excavation. Within urban areas, surface restoration can vary from surface patches to full width pavement with curb and gutter, and may include sidewalk replacement. For surfaces paved in the past five years, half width or full width pavement replacement may be required. For a minor arterial, half-width pavement replacement will cost approximately $150 per lineal foot. Conversely, there are some situations where only minor trench restoration is required at a cost varying between $1.10 to $2.00 per inch-dia-ft for pipes between 60 and 24 inches in diameter respectively.

Pipeline Cost Model

A cost model was developed to account for these site specific factors. This model is intended to provide an improved level of accuracy over that developed in the Wastewater 2020 project. To provide a more refined cost estimate, this model provides the flexibility to account for site-specific conditions that are likely to be known at the planning level. The assumptions included in the new cost model are outlined in Table 1. These assumptions and unit costs were developed from a review of recent contractor bid tabulations and the 1999 Washington State Department Of Transportation review of cost estimates. The output from the cost model and proposed user interface is included in Appendix B. It is anticipated that this cost model will be refined and developed into a simple Access Database or Visual Basic tool for use by the CSI project team.

Table 1. Pipeline Costs

Item	Units	Assumption/Unit Cost
Mob/demob	LS	10%
Layback	FT:FT	1 horiz:5 vertical
Trench Safety (Box)	SF	$0.50
Excavation	CY	$10
Imported Backfill	CY	$25
Place Native Backfill	CY	$5
Spoil Load and Haul	CY	$10
Asphalt Paving	SY	$50
Manhole Spacing	feet	400

The costs in the model for the "basic" project are based upon the following parameters:

- Locally supplied rubber gasketed concrete pipe, ASTM C-14, Class 3 for 8- to 10-inch diameter and ASTM C-76, Class V pipe for 12-inch and larger,
- Imported material is always used to backfill within the pipe zone,
- All spoiled excavation is hauled away (5 mile haul with traffic allowance),
- Trench safety is always applied,
- Trench sump dewatering is used to dewater the trench,
- Some traffic control is needed on the typical project, and
- Existing utilities and surface restoration are not significant additional costs.

To obtain a range of costs, the following cost increases have also been applied to the basic cost model:

- The entire trench is backfilled with imported material,
- Dewatering wells to dewater the trench, and
- Additional costs for typical trench pavement restoration and relocating utilities.

The cost model accounts for variable depth of cover, trench layback, and pipe diameter on trench geometry. These parameters affects the costs for excavation, backfill, trench safety and surface restoration. Modeled costs for pipe installation are included in Table 2. These modeled costs are reflective of four different pipe installation conditions:

1. The "basic" project costs as outlined above.
2. The "basic" project costs plus all import fill, and haul all excavation materials.
3. The "basic" project costs with imported fill plus additional costs for typical pavement restoration and relocating existing utilities.
4. The "basic" project costs with imported fill plus additional costs for typical pavement restoration, relocating existing utilities, and dewatering wells.

Table 2. Modeled Gravity Sewer Construction Costs

Diameter (in)	Base Cost ($/ft)	Base Cost with Imported Fill ($/ft)	Base Cost with Imported Fill, Paving, & Utilities ($/ft)	Base Cost with Imported Fill, Paving, Utilities, & Dewatering ($/ft)
8	$111	$195	$281	$331
10	$123	$211	$298	$348
12	$134	$225	$314	$363
15	$156	$252	$354	$398
18	$168	$269	$374	$418
21	$182	$288	$395	$439
24	$216	$327	$447	$491
27	$227	$344	$466	$510
30	$271	$393	$517	$561
36	$330	$462	$612	$645
42	$383	$525	$680	$735
48	$452	$604	$774	$829
54	$554	$717	$891	$935
60	$679	$852	$1,052	$1,118
68	$758	$941	$1,146	$1,212
72	$855	$1,049	$1,279	$1,334
78	$965	$1,169	$1,404	$1,459
84	$1,068	$1,282	$1,543	$1,620
90	$1,236	$1,460	$1,726	$1,792
96	$1,389	$1,624	$1,894	$1,960

The modeled costs compare well with those from past Metro/KCWTD projects adjusted for inflation. These past project costs are included in Appendix A and summarized in Table 3. In addition, the pipeline costs developed in this model were compared to those developed in the Wastewater 2020 project. This comparison of the Wastewater 2020 estimated costs and the modeled costs for similar assumptions as those in the Wastewater 2020 report are included in Appendix C.

Table 3. Open–Cut Base Construction Unit Costs

Pipe	Cost[1] ($/inch-dia-ft)	
	Mean	Typical Range[2]
Force mains	$9.50	$7.50 - $12.00
Gravity Sewers (Underground)	$12.00	$8.00 - $16.00

Notes:
(1) Costs based on ENR Seattle CCI = 7,000.
(2) Typical range is +/- one standard deviation.

Pipes - Microtunneling

Microtunneling is used where topographical features, trench depth, or existing facilities make the use of open-trench construction impractical or prohibitively expensive. Microtunneling allows for tight grade and alignment tolerances, so it is suitable for both gravity sewers and force mains. The mobilization costs for microtunneling are significant, so shorter projects, especially with pipes smaller than 18-inch diameter pipes are typically more expensive on a per inch diameter lineal foot basis than longer jobs involving larger pipe (Table 4). Factors that can significantly increase the cost of a microtunneling project above the unit costs cited in Table 4 include the following:

- Deep drive and receiving shafts and high groundwater - Increase the cost of microtunnel access shaft construction.
- Cobbles and boulders - Increase the cost of the microtunnel drive and risk associated with the drive.

Table 4. Microtunneling Unit Costs

Inside Diameter (inches)	Cost[1] ($/inch-dia-ft) Length of Drive (feet) <1,200	Cost[1] ($/inch-dia-ft) Length of Drive (feet) ≥1,200
<18	$41	$30
≥18	$36	$27

Notes:
(1) Costs based on ENR Seattle CCI = 7,000.

Each access shaft for a microtunneling project generally costs at least $50,000 and varies significantly with soil conditions, groundwater, depth and pipe size. Based on a review of a few microtunnel access shafts, shaft construction ranges from $3,500 to $11,000 per foot of depth. High groundwater and deep shafts increase the cost on a per foot of depth basis.

Pipes - Conventional Tunneling

Conventional tunneling is commonly used for pipes six feet in diameter and greater. In the KCWTD system, tunneling has been used for large interceptors and to provide storage for protection against wastewater overflows. As is the case with microtunneling, the mobilization costs for tunneling are significant, so shorter projects, especially with segments smaller than 9-foot in diameter are typically more expensive on a per inch diameter lineal foot basis than longer jobs involving larger pipe (Table 5). Factors that can significantly increase the cost of a tunneling project above the unit costs cited in Table 5 include the following:

- Deep access pits - Increase the cost of tunnel access shaft construction.
- High groundwater - Increase the cost of tunnel access shaft construction.
- Varying ground conditions - Increase the cost of the tunnel drive and risk associated with the drive.

Table 5. Tunneling Unit Costs

Inside Diameter (feet)	Cost[1] ($/inch-dia-ft)	
	Length of Drive (feet)	
	<1500	≥1500
<9	$31	$26
≥9	NA	$20

Notes:
(1) Costs based on ENR Seattle CCI = 7,000.

PUMP STATIONS

KCWTD pump stations typically consist of wet well- dry well facilities with standby power and an architecturally treated superstructure. Since the KCWTD has certain requirements for pump stations, only KCWTD pump stations historical costs were used to develop planning level cost curves and parameters for new pump stations.

There are several parameters that influence the cost of a pump station including the following:

- Firm Capacity – Cost increases fairly linearly in proportion to capacity.
- Total Discharge Head (TDH) – KCWTD has one pump station, the Richmond Beach Pump Station that has a design TDH greater than 350 feet. This pump station has three sets of two pumps in series resulting in a significantly higher cost than pump stations with a similar firm capacity.
- Excavation Depth – Typically, deeper pump stations are more expensive, although based a review of KCWTD facilities, a clear linear correlation could not be established.

Based on a review of KCWTD pump stations, including an analysis of these parameters, pump station cost curves and tables were developed (Table 6 and Figure 2).

Table 6. Pump Station Unit Costs

Criteria		Cost[1] ($/gal firm capacity)
TDH (feet)	Excavation Depth (feet)	
<350	<40	$0.40
<350	≥40	$0.50
≥350	NA	$0.90

Notes:
(1) Costs based on ENR Seattle CCI = 7,000.

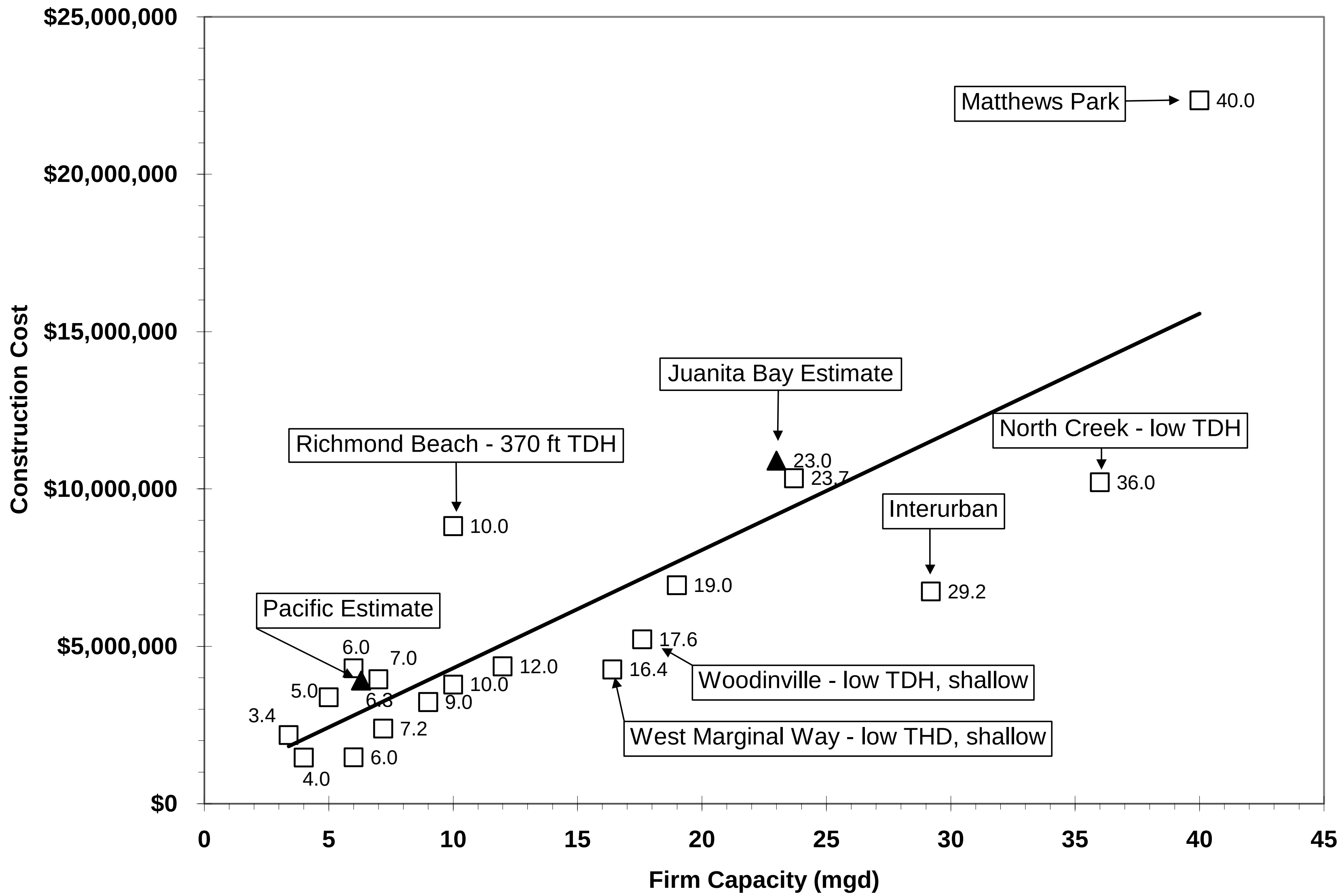

Figure 2. Pump Station Construction Cost Curves

OFF-LINE STORAGE FACILITIES

Cost curves were developed for off-line storage facilities from previous project costs and updated cost curves (Figure 3). The off-line storage/treatment facilities in Michigan used to develop the upper cost curve in most cases include screening, basin flushing equipment, dewatering by pumping, and odor control equipment. Since KCWTD facilities will most likely include similar equipment, the upper cost curve should be used for initial cost estimates.

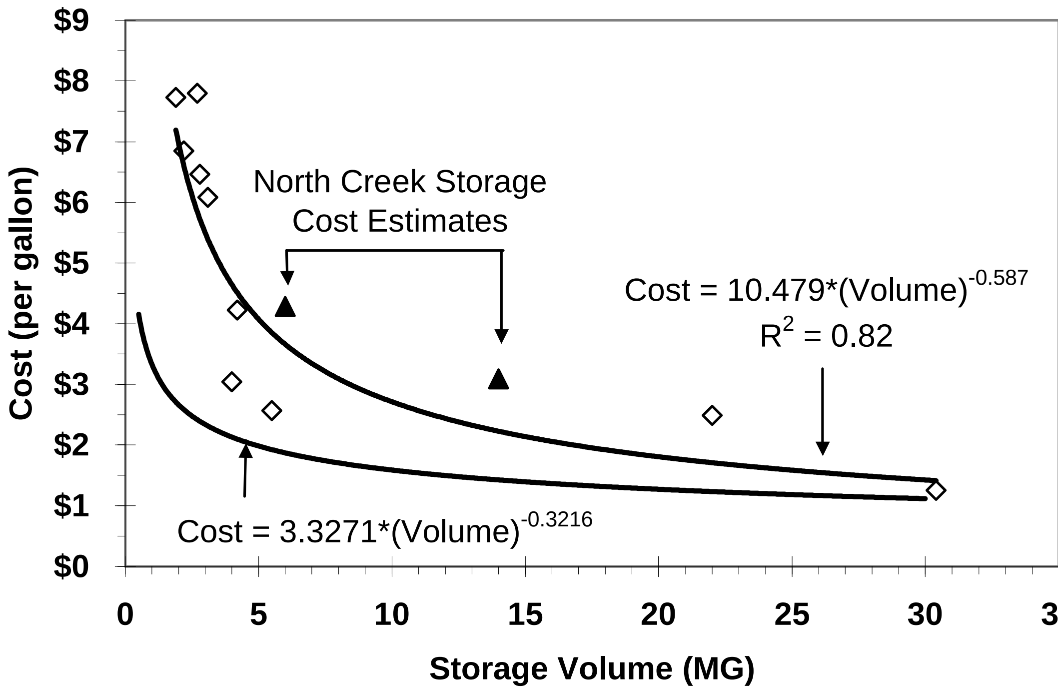

Figure 3. CSO/SSO Off-line Storage Facilities

To develop a more accurate cost estimate than allowed by the cost curves, site specific factors would need to be included. The site-specific factors that affect storage facility construction cost include the following:

- **Land Acquisition –** Acquisition of new right-of-way can add to the cost of construction over the cost of a facility within KCWTD property. Since acres of land may be required for storage facilities, these costs are not insignificant. For Wastewater 2020 Plus a right-of-way land costs varied from $6.90 for rural areas to $18.00 per square foot for urbanized areas plus a contingency of 45 percent.
- **Excavation Depth –** If the storage facility is to be filled by gravity, the depth of the influent sewer to the storage facility will define the maximum water surface elevation in the storage facility.

- **High Groundwater –** Dewatering wells and/or wellpoints will be required when the groundwater is above the bottom of the excavation. In addition, the high groundwater will require more expensive watertight shoring systems such as driven steel sheet piles or secant piles. In addition, measures to prevent tank flotation such as additional structural weight, base flanges to increase the soil uplift resistance, and tension uplift piles will be required to counteract the buoyant uplift forces when the groundwater is above the top of the storage facility.
- **Subsurface Conditions –** When native soils are unsuitable for trench backfill, imported backfill or controlled density fill may be required, especially adjacent to the structure.
- **Existing Utilities –** Avoiding and/or relocating existing utilities may be required in more highly developed urbanized areas. The cost curves do not include utility relocation. The area in which the facility will be located should be reviewed to determine if relocation of existing utilities will be required.
- **Surface Restoration –** Surface restoration of the area above the storage facility can substantially increase the cost of the facility. Typically, storage facilities are constructed outside of the street right-of-way, so pavement restoration would rarely be required. However, the area above the facility may be used for a park or other recreational uses. Whether or not these costs should be included in the cost of the facility will need to be determined on a site-specific basis.

TOTAL PROJECT COSTS

The focus of this report has been on total construction costs for a project. Before a project can be bid, the project must be planned and designed, and occasionally land and easements must be acquired. Based upon historical and projected KCWTD estimated, these costs as a percentage of the total capital improvement projects are summarized in Table 7. These non-construction related costs result in a construction to project cost multiplier of 1.5 (1/0.666) to obtain the total project cost.

Table 7. Task Costs as Percent of the Total Project Cost

Task	Percent of Total Project Cost
Planning	8.7
Predesign	4.1
Design	11.8
Construction	66.6
Closeout	5.4
Land Acquisition	1.9
Contingency (Not Construction Contingency)	1.6

APPENDIX A

PREVIOUS PROJECT COSTS

APPENDIX B

PROPOSED COST MODEL

APPENDIX C

COMPARISON OF MODELED AND PLANNING LEVEL WASTEWATER 2020 PROJECT COSTS